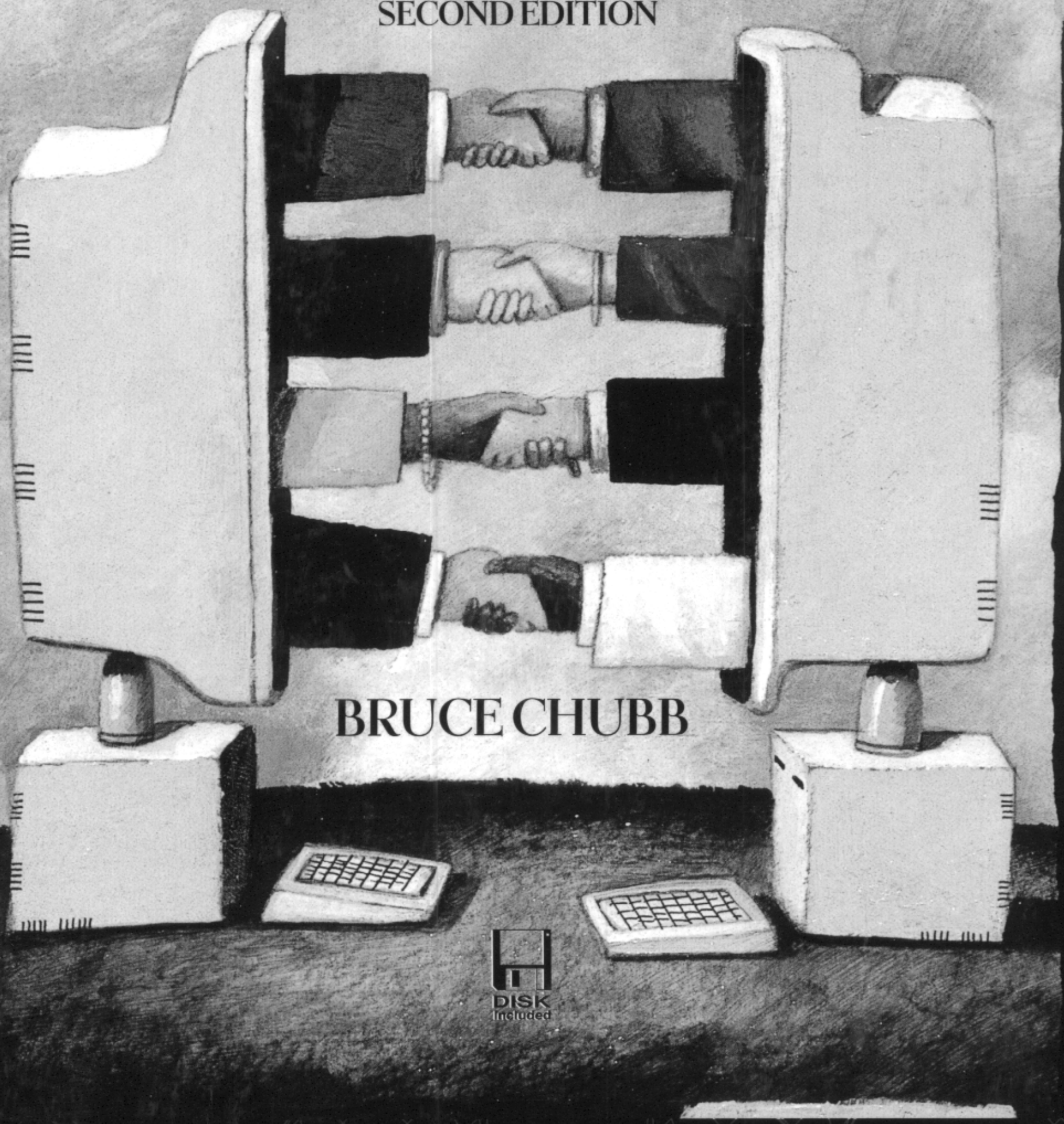
BUILD YOUR OWN UNIVERSAL COMPUTER INTERFACE

SECOND EDITION



BRUCE CHUBB

DISK
Included

Contents

Introduction *xi*

1 Basics for Building a Computer Interface *1*

Example UCIS Applications *2*
How the Universal Computer Interface System Works *4*
System Options *7*
Introduction to Software *8*
Binary Number System *10*
Hexadecimal System *12*
Assembling Your Own Interface *15*
UCIS Parts *16*
PC Card Soldering *20*
Cleanup and Inspection *21*
Test Meters *24*
System Troubleshooting *25*
System Reliability *26*

2 Selecting the Best Interface Options *27*

Versatility and Adaptability *27*
Computer Selection *28*
Looking at Options *30*
System Cost *30*
Parallel or Serial? *31*
Attributes for Selecting the Parallel (IBEC or UBEC) Approach *33*
Attributes for Selecting the Serial (USIC) Approach *34*
Narrowing the Choice *36*
Distributed Serial Systems *37*
Combined Parallel/Serial Systems *39*

3 The Internal Bus Extender Card *41*

Bus Fundamentals and the *x*86 Computer Family *41*
Extended Memory-Mapped I/O *44*
Predecessor Computers *44*
The IBM PC, XT and Their Compatibles *45*
The *x*86 Series *46*
IBEC Functions *49*
IBEC Schematic *53*
IBEC Parts *57*
IBEC Assembly *60*

4 Universal Serial Interface Card *63*

Serial Interface Standards *63*
Universal Serial Interface Card *67*
USIC Functions *69*
USIC Schematic *70*
USIC Parts *73*
USIC Assembly *74*
RS-232/422 Conversion Card *78*

5 Configuring and Installing the IBEC *83*

Stand-alone Testing *83*
Selecting the Desired I/O Mode *88*
Determining UCIS Starting Address *89*
Setting IBEC DIP Switches *98*
Inserting the IBEC into Your Computer *101*

6 The Universal Bus Extender Card *103*

UBEC Functions *103*
The UBEC Schematic *105*
UBEC Parts *107*
UBEC Assembly *110*
UBEC Enclosures *113*

7 Connecting UBEC to Your Computer *115*

Memory-Mapped or Port-Mapped I/O *115*
Determining the UCIS Starting Address *118*
Computer Bus Adapter Cards (CBACs) *119*
Computer Connections *119*
Assembling and Installing the IBPC *130*
Hardwiring Without an Adapter *134*
Other Computers *135*

8 Digital I/O Circuits and Test Card *137*

I/O Motherboard *138*
Address Decoding *140*

Digital Output Card Schematic *141*
Optional Output Card Configurations *144*
Building the Digital Output Card (DOUT) *146*
Digital Input Card Schematic *152*
Optional Input Line Filtering *153*
Building the Digital Input Card (DIN) *155*
Building a 5-Vdc Power Supply *159*
Building the Digital Output Test Panel *166*
Assembling Wraparound Test Cable *169*

9 Testing the Parallel (IBEC-Based) System *173*
Initial System Testing *173*
Output Card Test Program *175*
Conducting the Test *179*
In Case of Difficulty *179*
Automated Wraparound Test Program *181*
Conducting the Test *182*

10 Serial Interface Software *187*
General Message Format *187*
Protocol Subroutines *193*
Initialization of Variables *198*
Application Program Format *199*
Program Timing Considerations *202*

11 Testing the Serial (USIC-Based) System *203*
USIC Testing *203*
Output Card Test Program *207*
In Case of Difficulty *211*
Automated Wraparound Test Program *213*
Conducting the Test *215*

12 Testing the Parallel (UBEC-Based) System *217*
Initial System Testing *217*
Output Card Test Program *221*
In Case of Difficulty *222*
Automated Wraparound Test Program *223*

13 Connecting External Hardware to the I/O Cards *225*
Basic Output Connections *225*
Driving Heavy Loads *229*
Basic Input Connections *230*
Simplified Wiring *232*
Decoding Output *232*
Encoding Input *235*
Sample Decoder Card *238*

Stepper Motor Control *242*
Preview of Additional Circuits under Development *245*
Using Current-Sourcing Output Cards *247*
Driving Matrixed Outputs *247*
Good Ground Wiring *249*

14 Adding Analog Interface Cards to a UCIS *253*
Digital-to-Analog Converter (DAC) Chips *253*
DAC Output Card *256*
Building the DAC Card *258*
Analog-to-Digital Converter (ADC) Chips *263*
ADC Input Card *265*
Building the ADC Card *269*
Motor Speed Control *272*
Building the CCT Card *275*
Pulse Power Control *281*

15 Generating I/O Handling Software *285*
Basic UCIS Application Steps *285*
Incremental Addressing to I/O Cards *286*
Functional I/O Example *289*
Recommended I/O Tables *289*
Programming Format for a Real-Time Loop *292*
Making I/O Addressing Easy *292*
Reading and Unpacking Input Bytes *295*
Packing and Writing Output Bytes *297*
Sample I/O Program Using the IBEC or UBEC *297*
Backslash vs Forward Slash *300*
Apple I/O *300*
Sample I/O Program Using USIC *301*

16 Original I/O Circuits and Test Card *305*
The I/O Chip *306*
Output Card Schematic *306*
Building the Output Card *308*
Input Card Schematic *312*
Building the Input Card *312*
Building the Test Panel *315*

17 Sample Interface Application: External Hardware *319*
Introduction to the Application *320*
Computer Cab Control *321*
Optimized Detection *323*
Switch Machine Control *334*
Block Power Switching *344*
Block/Cab Assignment Panel *351*

Directional Input *354*
Cab Display Card *356*

18 Sample Interfacing Application: System Hookup and Software *361*

Example Layout *361*
I/O Tables *363*
System Wiring *364*
Application Software *367*
Monitor Status Display *382*
Monitor Display Subroutines *384*
Simulating UCIS Input *384*
Program Modification Using USIC *385*
Automated Diagnostics *386*
Automated Operation *389*

Appendixes *393*

A Circuit Board Order Blank and Circuit Artwork *395*
B Electronic Parts Ordering: Address Summary *403*

Index *405*

Introduction

This book provides in-depth coverage of how you can build your own universal computer interface system (UCIS). The book details the complete technology of computer interfacing from theory to step-by-step assembly instructions. Both hardware and software are covered in depth. The UCIS works with everything from the newest Pentium back to the earliest IBM PC, XT, and their compatibles. It works with the early Commodores. It works with the earliest Apple II up through the latest Macintosh. The result is that "You can hook up most any computer to UCIS and have it perform any function you want it to perform."

Nearly 10 years of UCIS experience have been achieved since the original edition was published, and I've worked personally with thousands of UCIS users in a wide variety of applications. This second edition takes advantage of this experience base to help you better meet your interfacing requirements. Where original readers might have had difficulty, the material presented in this second edition has been enhanced for added clarity and completeness.

New circuits and new circuit boards are introduced, including an entirely new internal bus extender card that fits directly into Pentium and x86-class computers. Entirely new general-purpose digital input and output cards are introduced. More coverage is provided for the distributed serial option, enabling I/O devices to be placed closer to the objects they monitor and control. Software examples are expanded, with increased emphasis on using different languages.

It is easy to build a UCIS using the ready-to-assemble circuit cards available from the readily accessible sources provided in this second edition. An order blank is included. For readers desiring to get started in applying the interface without building the components, new sources are provided for purchasing fully assembled and tested interface cards. Alternatively, circuit artwork is provided for those wishing to fabricate their own circuit cards. Recommended source lists are provided for easy location of all electronic parts.

The UCIS does it all by providing direct bus-connected parallel, serial, and distributed serial interfacing for the whole spectrum of popular computers. For the serial case, the UCIS handles multiple standard hookup options, including RS-232, RS-422, and 20-mA current-loop, plus it makes provision for an RS-232 to RS-422 converter.

The UCIS provides tremendous expandability, with up to 1536 separate I/O lines in the parallel and basic serial options and up to 24,576 I/O lines with the distributed serial option.

This second edition provides extensive software coverage including standard serial protocol subroutines, real-time software control, multiple application examples, system test programs, and automated diagnostics. All software is incorporated in a 3.5-in disk enclosed with the book. To fit the backgrounds and needs of different readers, examples are included in an assortment of languages including BASIC, QBasic, QuickBASIC, Visual Basic, Pascal and C++.

Step-by-step instructions are included for building general-purpose digital input, digital output, analog-to-digital (A/D), and digital-to-analog (D/A) cards for connecting to all types of external hardware, such as switches, LEDs, lamps, relays, digital circuits, potentiometers, stepper motors, thermocouples, dc motors, and more. Comprehensive illustrative application examples are provided including model railroading computer cab control, automatic signaling, and train speed/direction control.

There are many different computers, and most every other interfacing book covers either one particular computer, or no specific computer at all (by treating the interface in only a generic sense). As proven with 10 years of UCIS experience, interfaces that work require specific detailed knowledge of the idiosyncrasies of each computer in terms of pinouts, line functions, polarities, and timings. In this book, all the required details for most every popular computer have been worked out. They are spelled out in step-by-step assembly detail for straightforward construction of an interface that really does the job.

The contents of this second edition provide the full complement of required information applicable to the neophyte with no prior electronic/computer experience, or to the professional electrical engineer. Following the step-by-step assembly and test instructions requires no prior experience to build a functional interface that works.

The first edition proved that this book, and the resulting UCIS, have universal appeal to the broadest possible audience. The industry technology trend is toward more effective applications of computers as part of real-time systems. This book shows specifically how a computer can be mated effectively to any type of external hardware for real-time control by software.

Numerous universities, colleges, and technical schools have developed UCIS applications. Instructors, having applied the text, declare that they see the material well-suited for classroom use. It is especially helpful when used as a supplementary text for special lab projects involving a computer connected to hardware, and for college and technical courses in digital computer interfacing and real-time software development.

In addition to the major commercial/industrial applications and the expanding educational interest, this book provides significant insight for the electronic and computer hobbyist. Experience is not required. People who have successfully constructed the UCIS include those with no exposure to any electronic project up to electrical engineers who daily work on digital electronics. In other words, anyone can build the UCIS. If you absolutely had to label this book, it is for the beginner to

intermediate hacker/developer/system user; however, the expert can use the material to effectively and quickly build up to any level of interface complexity desired.

The text is set up so the reader can easily skip the theory and functional material and go right to the construction steps if desired. Likewise, if interest is exclusively in parallel interfacing, the reader is instructed where to skip over the serial interface material and vice versa. For those readers wishing to purchase their interface cards fully assembled and tested, they can jump right to the application examples.

Chapter 1 sets the stage for interfacing by whetting the appetite with a look at typical UCIS applications. It defines how the UCIS functions. An overview look at the available interface options is presented, followed by an introduction to software. The procedures for assembling your own UCIS are generally described, as well as a readily accessible source for purchasing the ready-to-assemble circuit cards. Additionally, new sources are provided where the interface boards can be purchased fully assembled and tested. The chapter concludes with discussions on circuit card soldering, system troubleshooting, and system reliability.

Chapter 2 provides added insight into selecting the best set of interface options to meet a particular need. Topics include computer selection and which interface options work with which computers, system cost, and what it takes to switch from one option to another. The attributes provided via direct parallel attachment to the computer's main bus, serial, and distributed serial interfacing are presented. Commonality of the major interface elements is stressed, along with the tailoring necessary to fit specific computer capability and external hardware requirements. System modularity and expandability as well as forward and backward compatibility are presented.

Chapter 3 begins the assembly of the UCIS parallel interface option by constructing the internal bus extender card (IBEC)—a new card designed specifically for interfacing to the Pentium, 486, 386, 286, and AT-class computers. Fundamental bus architecture is explained, along with interfacing highlights for the $x86$ computer family and their important predecessors. Also provided is a description of the IBEC functions, including signal buffering, address decoding, I/O mode selection, and data line control. Once functionality is understood, touring the schematic presents further insight into how the IBEC handles interface demands. Easy-to-follow, step-by-step assembly instructions are presented in a format that leads to a quality operational system.

Chapter 4 introduces the UCIS serial interface option by describing the universal serial interface card (USIC). Serial interface standards are described, including 20-mA current loop, RS-232, and RS-422, all of which are handled by the USIC. The operation of the USIC is explained first from a functional viewpoint and then via its schematic. This is followed by step-by-step assembly instructions. The chapter also covers assembling an RS-232 to RS-422 conversion card for setting up the distributed serial option.

Chapter 5 covers IBEC installation in Pentium, $x86$, and AT-class computers, as well as the IBM System/2 Model 30 and the earlier IBM PC, XT, and their compatibles. Initial card testing is followed by how to select different I/O modes, including memory-mapped and port-mapped I/O. The reader is led through proper card configuration procedures and then operational testing with the installed IBEC.

Chapter 6 expands the UCIS parallel interface option by describing the universal bus extender card (UBEC). Also provided is a description of the UBEC functions and a schematic tour. The UBEC assembly instructions are presented, including how to set jumper configurations and part substitutions to effectively mate the card with a multitude of different computers.

Chapter 7 explains how the UBEC is connected to the computer using either memory-mapped or port-mapped I/O. The chapter provides extensive coverage of computer connections and the use of computer bus adapter cards (CBACs) for a wide range of computers including the IBM PC, XT, XT-286, AT, 286, 386, 486, Pentium, SYSTEM/2 Model 30, the TRS Color Computer family, the Commodore family, and the entire Apple II family. Even a hardwiring example shows how the UBEC can be tied directly into computers that do not have an available JLC adapter card. Covering such a broad spectrum makes it easier to figure out how to mate with any particular computer requirement.

Chapter 8 covers building a newly designed set of general-purpose digital I/O circuits and a test card. General understanding of I/O handling is achieved by presenting address decoding and I/O card functional descriptions. Step-by-step assembly instructions are provided for the I/O motherboard, general-purpose digital I/O cards, building a 5-Vdc power supply, a test panel card and a wraparound test cable.

Chapter 9 covers testing of the parallel IBEC-based interface. Simple test software is presented, along with information on how to read the test LEDs built into the IBEC design. Recommended courses of action are exemplified for areas of difficulty. Testing is completed by using a provided output card test computer program followed by a complete wraparound test program guaranteeing correct operation of the complete system.

Chapter 10 explains in an easy-to-understand format the complexities of serial interface software. Topics include general message formats, protocol subroutines, and the initialization of program variables. Complete UCIS standard protocol software is provided for direct reader applications. Program timing considerations are discussed, along with recommended application program format for ease in real-time user software development.

Chapter 11 covers testing of the serial USIC-based interface. The reader is led through the complete testing process starting with visual inspection and simple voltage testing. Specific debugging steps are defined. Testing is completed by using provided serial versions of the output card test computer program followed by a complete wraparound test program.

Chapter 12 covers testing of the parallel UBEC-based interface. The reader is led through the complete testing process starting from simple continuity and voltage testing up through using test programs guaranteeing complete system operation.

Chapter 13 defines how to make I/O card connections to a broad range of external hardware including lamps, LEDs, panel switches, pushbuttons, limit sensors, other digital circuits, relays, stepper motors, and a booster circuit for driving heavy current-demanding loads. Decoding and encoding circuitry is presented to further simplify system wiring along with how to take advantage of current-sourcing output cards and how to drive matrixed outputs. The chapter also explains the design and assembly of an example decoder card, as well as the principles of good ground wiring.

Chapter 14 increases the reader's available repertoire by adding analog interfacing cards to the UCIS. Digital-to-analog converter (DAC) chips are described, and then via step-by-step assembly instructions, a complete three-channel UCIS-compatible DAC card is generated. The same proven process is repeated for understanding and assembling a UCIS-compatible three-channel analog-to-digital converter (ADC) card. Motor speed control is covered as a further example, using a special throttle card followed by the application of pulse power control for improved slow-speed operation.

Chapter 15 covers the important topic of generating I/O-handling software. The basic steps for generating effective I/O software are explained so they are applicable to the full range of application needs. Recommended easy-to-use I/O tables are provided to help establish program organization and correctness. Program format for the real-time loop is presented along with making I/O addressing easy. Important methods define how to read and unpack input bytes and how to pack and write output bytes. To solidify the procedures, an I/O program example is prepared using the IBEC, then the UBEC, and then repeated using the USIC.

Chapter 16 covers building the original I/O circuits and the corresponding test card. Although not as sophisticated as the new card designs, these single-sided versions still have plenty of merit, especially for systems where the reader desires to fabricate his or her own cards.

Chapter 17 starts a very meaningful two-chapter interface application example by defining and building up a set of external hardware to interface a model railroad to a computer using UCIS. This example of UCIS application is designed to go a long way toward helping every reader adapt UCIS to best meet his or her specific interface application. The cards discussed might appear at first to have a specialized purpose; however, in reality the technological ideas presented (as well as the circuits that result) have far-reaching implications applicable to most any interface project.

Chapter 18 completes the comprehensive interface example by hooking up the system and generating the application software. Additional topics include setting up a monitor status display, preparing display subroutines, simulating UCIS inputs for program testing, and program timing. Once the software is complete for IBEC and UBEC, it is then regenerated for USIC users followed by a general discussion of further advanced capabilities provided by automated diagnostics and fully automated operation.

Hardware

How to construct and connect an interface that lets your computer control any external hardware

Ever consider using your personal computer to control the electrical appliances and systems in your home or office? It's a complex topic, but the task itself is very easy to accomplish—thanks in large part to Dr. Bruce Chubb's groundbreaking work, the first to make a device called the universal computer interface system (UCIS) accessible to everyone, from neophytes to professionals.

Now he has updated that classic guide, providing complete, step-by-step instructions for assembling a UCIS and connecting it to virtually any of today's most popular computers. The Second Edition features:

- Serial and parallel interface connections for IBM PCs and compatibles, XT, XT-286, AT, 386, 486, and Pentiums, plus the complete line of Apple/Macintosh machines
- A ready-to-use disk containing all of the computer code necessary for hardware implementation
- Information on general purpose input/output, analog-to-digital and digital-to-analog cards for connecting to all types of external hardware including switches, LEDs, lamps, relays, and motors
- New description of interfacing stepper motors, a very important development for emerging robotics applications

Here is the boundless technology of computer interfacing, presented in a unique style that is both detailed and amazingly simple to follow. Whether you are a beginning hobbyist or an electronics engineer, Bruce Chubb once again provides everything you need to know about hardware, software, interface theory, and building-block assembly of a UCIS that can be used to control practically any electrical device you can imagine.

$34.95 U.S.A.
P/N 011689-X
PART OF
ISBN 0-07-912639-1

9 780079 126399 90000

Cover Design: Paul Agresti
Cover Illustration: SIS/Dave Cutler Studio, Inc.

Visit us on the World Wide Web at
www.books.mcgraw-hill.com

McGraw-Hill
A Division of The McGraw-Hill Companies